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### Shared circuits in language and communication

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Although AVHs are classified as a first-rank symptom of schizophrenia, they may not necessarily signify pathology and may best be understood within the wider context of the development of inner speech (Jones & Fernyhough 2007a; 2007b). In Vygotsky's theory of the social origins of higher mental processes, inner speech represents the end point of a developmental process in which external conversation gradually becomes internalized to form verbal thought (Vygotsky 1934/1987). Like its semi-covert developmental precursor, private speech, inner speech retains the dialogic nature of the external discourse from which it derives. Fernyhough's four-stage model of the development of inner speech as conceptualized by Vygotsky suggests two distinct forms of dialogic inner speech (Fernyhough 2004): *expanded inner speech*, where the give-and-take quality of external conversation permeates the verbal mentation; and a *condensed* variety of inner speech, where inner speech becomes "thinking in pure meanings" (Vygotsky 1934/1987), having lost most of the acoustics and structure of external dialogue. According to Fernyhough's (2004) theory of AVHs, which draws on Vygotskian ideas about the developmental significance of inner speech, AVHs result from the temporary re-expansion of condensed inner speech, particularly under conditions of stress and cognitive challenge. The acoustic properties of the voices in inner dialogue are thus not attenuated but are experienced fully. The question then is how it is possible that cognition (inner voice) produced by self may be experienced as produced by other.

The cognitive dysfunction that results in the failure to differentiate self from other in inner speech may be explained by a forward model similar to the one underpinning Hurley's layer 2. SCM relies on the forward model of motor control as proposed by Miall (2003) to postulate the subpersonal process that predicts the consequences of motor commands and compares them with the desired state. In her article on delusions of alien control, Blakemore (2003) uses this model to explain how an internal predictor uses information about intentions to enable the distinction between self-generated and externally generated sensory events. The forward model is dysfunctional when it cannot accurately predict the sensory consequences of a movement based on the efference copy of the motor command. This results in sensory discrepancy and a failure to cancel the refference or actual feedback, so that the self-produced movement feels externally caused (Blakemore 2003; see also Frith et al. 2000b). Although developed to explain abnormalities involving overt actions, this forward model has recently been applied to inner speech (Jones & Fernyhough 2007b). Jones and Fernyhough's application proposes a direct causal mechanism leading from a malfunction of the predicted state to the experience of inner speech as being of alien origin. When the brain either produces a degraded predicted state or fails to produce a predicted state at all from the initial inner speech motor command, the consequence is that an emotion of self-authorship is not felt and instead the inner speech is experienced as authored by an other.

For any model of the mind or cognitive functioning to be complete, it must relate to the brain. Thus, we need to understand the neural underpinnings of the predicted-state mechanism proposed by the forward model. This may require investigating networks, such as the interactions between perceptual and motor areas (Jones & Fernyhough 2007b). For example, Leube et al. (2003) have suggested that neurological activity associated with a deficit in the efference copy mechanism may involve the cortical network that de Vignemont and Fournier (2004) found implicated in action attribution, including the prefrontal and the parietal cortex, the supplementary motor area, and the cerebellum. In terms of AVHs, Shergill et al. (2000) examined functional magnetic resonance imaging (fMRI) scans of patients with schizophrenia made while the patients were experiencing AVHs. They noted that the pattern of activation observed during AVHs was remarkably similar to that seen when healthy volunteers engaged in auditory verbal imagery (AVI), which is produced when one imagines being spoken to by another person.

Specifically, Shergill et al. (2000) observed common activation of bilateral frontal and temporal gyri, along with right-sided precentral and inferior parietal gyri. Increased supplementary motor area activation was associated with healthy participants generating auditory verbal images; however, the supplementary motor area (SMA) was only weakly activated during AVHs. Other studies have suggested a role for the right anterior cingulate gyrus (see Jones & Fernyhough 2007a and studies cited therein). Given that the parietal and cingulate cortices subserve attention to internal and external bodily space and the attribution of significance to sensory information, they provide a plausible neural substrate for the misattribution of self-generated inner speech to other (see Spence et al. 1997).

## Shared circuits in language and communication

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**Abstract:** The target article says surprisingly little about the possible role of shared circuits in language and communication. This commentary considers how they might contribute to linguistic communication, particularly during dialogue. We argue that shared circuits are used to promote alignment between linguistic representations at many levels and to support production-based emulation of linguistic input during comprehension.

Hurley's shared circuits model (SCM) provides a framework for investigating the role of emulation and imitation in social cognition. The SCM builds on two recent developments in cognitive neuroscience: Grush's (2004) notion of an emulator (originating from motor control theory) and the discovery of mirror and canonical neurons in monkeys. The target article specifically concentrates on the role of shared circuits in imitation, deliberation, and mindreading. However, it says little about their role in language and communication, which presumably underpin many of the cognitive abilities that Hurley focuses on.

Section 2.3.1 of the target article discusses various hypotheses about how imitation might support language. For example, Hurley argues that the "flexible articulated relations between means and ends in imitative learning could be an evolutionary precursor of arbitrary relations between symbols and referents" (para. 2) and that "mirror systems provide a common code for actions of self and other, and thus for language production and perception" (para. 3). Finally, she suggests that the "flexible recombinant structure of ends and means in imitation may be a precursor of recombinant grammatical structure in language" (para. 4).

However, section 3 contains surprisingly little about the relationship between the SCM (and its various layers) and language processing. In fact, it is only when discussing layer 5 (the full-blown model) that language is considered at all. This is in relation to how imitative learning together with learned manipulation of external symbols could support the rich structure of language. Hurley also speculates that language could assist layer 5 circuits in taking input off-line, thereby allowing for more advanced mindreading (e.g., in multi-person strategic deliberation).

By contrast, we suggest that lower layers of the SCM may play a crucial role in language processing, in particular during

interactive dialogue, which is the most basic setting for linguistic communication. Notice that some of the strongest evidence for perception priming action is from the language domain. For example, there are now a number of demonstrations of the priming of articulators during speech perception using transcranial magnetic stimulation (TMS) and electromyography (EMG) (Fadiga et al. 2002; Watkins et al. 2003). We have argued that, during dialogue, interlocutors tend to align their mental states at many levels, and that such alignment is largely a result of priming (Pickering & Garrod 2004). Indeed, successful communication appears to occur when interlocutors align their models of the situation under discussion. So it would be surprising if the “shared circuits” underlying imitation and mindreading did not also play an important role in this process. In fact, good evidence suggests that alignment of the situation model is supported by rapid and largely automatic alignment at many linguistic levels, such as sound (e.g., Pardo 2006), syntax (Branigan et al. 2000), and meaning of expressions (Garrod & Anderson 1987).

Such linguistic priming would arise at layer 3 of the SCM, just as it does for the chameleon effect (Chartrand & Bargh 1999). Hurley notes “the intimate relationship between the sharing of circuits for self and other and for action and perception: Layer 3’s shared informational dynamics for intersubjectivity presupposes layer 2’s shared informational dynamics for perception and action” (sect. 3.3, para. 3). We argue that just such a relationship holds between shared circuits for linguistic representations in communicators and shared informational dynamics for language production and comprehension (Garrod & Pickering 2004). In other words, covert and overt imitation (i.e., imitative production) at various linguistic levels promotes alignment or intersubjectivity between linguistic representations at those levels.

It is not only in relation to imitation that dialogue processing involves shared circuits. There is increasing evidence that language comprehension like action observation may use production-based (i.e., action based) emulation. In particular, we have argued that comprehension uses predictions based on simultaneous involvement of components of the language production system in the form of a Grush-style emulator (Pickering & Garrod 2007). Such an emulator uses the production system to make predictions (at various linguistic levels) about the input to the comprehension system and runs those predictions in real time. In this way, the system facilitates rapid interpretation and is robust in dealing with ambiguous or noisy language input. At the same time, by priming the production system, the emulator facilitates the rapid switching between comprehension and production during dialogue. Although this production-based emulator is used for comprehending speech, it is built out of exactly the same action-perception components as used in layer 3 of the SCM.

Incorporating control systems into shared circuits for social cognition is a welcome theoretical development. Here we have argued that such shared circuits can also be used to explain how interlocutors align their linguistic representations during dialogue, which ultimately supports successful communication. Indeed, communication is about sharing (with the Latin *communicare* meaning “to share” or “to make common”), so it should come as no surprise that linguistic communication depends upon shared circuits.

## Does one size fit all? Hurley on shared circuits

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**Abstract:** Hurley’s high level of generality suggests that a control-theoretic framework underpins all of the phenomena in question, but this is problematic. In contrast to the action-perception domain, where the control-theoretic framework certainly applies, there is no evidence that this framework equally applies to feelings and emotions, such as pain, touch, and disgust, where mirroring and simulational mindreading are also found.

Hurley’s target article is pitched at a high level of generality. It speaks broadly of shared circuits, control, mirroring, simulation, mindreading, and so forth, giving the impression that its major theses apply equally across all applicable types of cognition. But there is good reason to doubt that this is accurate, and it is not entirely clear whether Hurley really intends it. Important sub-themes of the target article seem principally aimed at the relation between action and perception – for example, the falsity of the “classical sandwich architecture” (sect. 3, para. 1). Is everything she says about action, perception, and feedback supposed to apply equally to other domains in which shared circuits, mirroring, and mindreading are found? The article’s level of abstraction leaves the distinct impression that the theses advanced at the various layers of analysis cut across all the domains, but that is dubious.

My chief worry centers on the relation between shared circuits (or mirroring) and control theory. Hurley is not alone in emphasizing such a connection (Gallese 2003; Wolpert et al. 2003). However, the case for tying the control-theoretic perspective to shared circuits, mirroring, and simulation is based mainly on the action-perception domain, where there is specific physiological, theoretical, and experimental evidence for efferent copy and reafferent input. Nothing of this sort exists, however, for a number of other domains where shared circuits and simulation are found.

To be specific, mirroring phenomena exist in several areas of cognition in addition to the motoric: in sensation, including pain (Jackson et al. 2004; Singer et al. 2004) and touch (Keyser et al. 2004), and in emotion (most clearly, disgust; see Wicker et al. 2003). But in these domains, there are no established feedback or control-theoretic phenomena of comparable importance – or any sort at all. Here is a brief review of the shared circuits (or mirroring) findings across multiple domains. The shared areas or circuits for action are the premotor cortex and inferior parietal lobule interconnected with the superior temporal sulcus (STS)/middle temporal gyrus (MTG); for disgust, the insula; for fear, (possibly) the amygdala; for pain, the anterior cingulate cortex (ACC) and anterior insula; and for touch, the somatosensory cortices. In all cases, observing what other people do or feel is transformed into an inner representation of what we would do or feel in a similar, endogenously produced, situation. In many of these cases, moreover, evidence drawn from lesion studies and imaging studies indicates that mirroring produces mindreading of others’ mental states (Goldman 2006; in press; Goldman & Sripada 2005). However, only in the case of action is there clear evidence of feedback loops that fit the control-theoretic framework. So the notion that systematic relationships between shared circuits, simulation, and mindreading crucially depend on control-theoretic mechanisms is unsupported. Yet that is what Hurley suggests, since her architecture of social cognition is erected on a control-theoretic foundation.

Hurley writes that “the shared circuits model (SCM) shows how subpersonal resources for control, mirroring, and simulation can enable the distinctively human sociocognitive skills of imitation, deliberation, and mindreading” (sect. 3, para. 1). Her two bottom layers of analysis highlight adaptive feedback control and prediction of effects for improved control, and the three higher layers are explained in terms of these lower-level mechanisms. She makes no attempt, however, to explain how feedback and control account for simulational, empathic, or mindreading properties related to sensation and emotion. Indeed, the latter are barely mentioned. The explananda listed at her top level, the personal-animal level, all involve action and behavior; yet the